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Modeling an ontology on accessible evacuation routes for emergencies

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ABSTRACT

Providing alert communication in emergency situations is vital to reduce the number of victims. However, this is a challenging goal for researchers and professionals due to the diverse pool of prospective users, e.g. people with disabilities as well as other vulnerable groups. Moreover, in the event of an emergency situation, many people could become vulnerable because of exceptional circumstances such as stress, an unknown environment or even visual impairment (e.g. fire causing smoke). Within this scope, a crucial activity is to notify affected people about safe places and available evacuation routes. In order to address this need, we propose to extend an ontology, called SEMA4A (Simple EMergency Alert 4 [for] All), developed in a previous work for managing knowledge about accessibility guidelines, emergency situations and communication technologies. In this paper, we introduce a semi-automatic technique for knowledge acquisition and modeling on accessible evacuation routes. We introduce a use case to show applications of the ontology and conclude with an evaluation involving several experts in evacuation procedures.

1. Introduction

When an emergency occurs or is going to occur, affected people need to know the location of safe places where they can shelter and routes for reaching them. In this way, depending on their abilities and the surrounding environment, users can be guided along such routes reducing the number of victims.

Within this scope, the preparedness phase has a crucial role in emergency management for defining an effective evacuation route diagram. Generally, depending on the area of interest, there is a security department in charge managing the evacuation plan, where, not only routes, but also procedures and responsibilities are identified. A support for this activity consists of simulations, guidelines, mathematical models, regulations and best practices that could help in the implementation of a valid evacuation route diagram.

In order to guarantee an effective evacuation for all people affected by a disaster, we think that a route diagram must include additional variables, such as user's profile (e.g. functional or contextual disabilities, elderly, and children), kind of emergency (e.g. typhoon, earthquake, and tornado) and any other exceptional circumstances (e.g. interrupted roads, collapsed exit). For example, when an emergency occurs in a building, a person with limited motor abilities needs a special route for escaping with the help of an assistant. Moreover, in this case the route cannot pass through stairs or narrow passages.

To make routes accessible for every user and emergency circumstance, it is crucial that tools used for the definition of the diagram acquire and share this information with other emergency management systems. For this reason, a standard for managing and distributing knowledge about accessible evacuation routes is needed as support for this activity.

The aim of this paper is to define a knowledge representation for providing adapted information about evacuation routes depending on emergency scenarios, user's profile and communication technologies. The proposed solution is based on a previous work (Malizia, Onorati, Díaz Pérez, Aedo, & Astorga-Paliza, 2010), where authors have developed an ontology called SEMA4A (Simple EMergency Alerts 4 [for] All). SEMA4A reflects the necessity of an interoperable knowledge for relating concepts about accessibility guidelines, emergency scenario and communication technologies for providing accessible notifications. The novelties introduce in this work can be summarized as follows: (1) giving to users an active role during the response phase by guiding them to a safety point (our previous work included only notifications about emergencies but no active guidance to escaping routes); (2) the extension of the ontology for including evacuation routes is performed introducing methodologies for semi-automatic knowledge identification, acquisition and modeling; (3) a use case (fire scenario) with

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the application of new technologies related to the new requirements demonstrating the applicability of the approach.

The extended version of SEMA4A aims at notifying users with, not only information about the specific situation, but also personalized instructions for reacting effectively and reaching the nearest safety point. The second contribution consists in applying an advanced methodology (with respect to the first version of SEMA4A) due to the dynamic characteristics of the knowledge base modeled for evacuation. Following the knowledge management life cycle (Maier, 2007), this methodology covers different steps: from knowledge identification to the organization through acquisition and creation. Moreover, in order to ensure an interoperable knowledge representation, the ontology has been implemented using the Web Ontology Language (OWL). Through this standard codification we are providing an open knowledge base for the integration with other systems and tools.

In order to show the applicability of SEMA4A, we have collaborated at the development of a prototype for sending notifications about evacuation routes. In such prototype not only the evacuation route, but also the visualization mode, is adapted considering the particular user's profile, the characteristics of the situation and using new interaction paradigms like augmented reality.

Finally, in order to show the validity of the proposed extension, we have evaluated it employing two different approaches: quantitative and qualitative. Results obtained from both methodologies demonstrate that the ontology has a high representative value for considered domains and consequently can be used as an interoperable base for adapting information about evacuation procedures.

In the second section, we present a summary of literature contributions about accessibility, emergency and evacuation models and systems. Successively, in the third section we introduce the proposed extension, specifying the applied methodology and describing the applicability of obtained result through a use case. In the fourth section, we present evaluation results for quantitative and qualitative evaluation. Finally, some conclusions and future works are discussed.

2. Background

2.1. Knowledge representations for accessibility and emergency

In literature, several interesting contributions have been introduced to define knowledge representations as a common and formal language to enable interoperability of different services. Focusing on the domain of accessibility, Yesilada et al. have developed a tool called Dante for making accessible web pages for people with visual impairments (Yesilada, Harper, Goble, & Stevens, 2004). Dante is based on an ontology called WAfA (Web Authoring for Accessibility) that contains concepts and relations that model the structure and navigation of web pages. Through WAfA, the proposed system provides annotations and tags for each element of a web page. In this way, a web page is made accessible for any reader and any users' profile.

Following the same idea, Lozano-Tello et al. have published the KAICO system that associates semantic tags to web pages in order to extract and communicate information to blind people (Lozano-Tello, Macías, Prieto, Sánchez, & Sosa, 2004). The system uses an ontology called OntoSaw for establishing a correlation between concepts on web pages and concepts on the accessibility domain. In this way, it is possible to determine if elements contained in a web page are accessible or not. The ontology has been defined starting from several interviews with people with visual impairments about their experience surfing the web.

Other interesting examples of knowledge representations can be also found in the emergency domain. Most relevant contributions are focused on the response phase and in particular on the lack of a common language among different organizations and agencies. One of them is the Emergency Response Ontology by Li et al. (2008). This ontology is a semantic representation of the emergency response workflow. Based on it, information systems for managing crisis situations can infer the next action to perform (according to defined procedures) and who is in charge of its execution.

Considering that we aim at adapting information about evacuation procedures to several variables, i.e. accessibility, emergency, technology and evacuation, we need to model an integrated representation of four different domains, obtained extending the SEMA4A ontology. On the contrary, previous contributions found in literature focus mainly on single aspects, like the users' profile (e.g. the OntoSaw ontology) or the emergency response (e.g. the Emergency Response Ontology).

2.2. The SEMA4A ontology

Providing alert notifications about current emergencies is crucial for reducing the number of victims and damages. In order to reach all affected people in every kind of situation, it is important to consider the users' needs and communication infrastructures available depending on the particular emergency. In 2010, the SEMA4A (Simple EMergency Alerts 4 [for] All) ontology was developed for correlating users' needs, technologies and relevant information about emergency situations (Malizia et al., 2010). This ontology can be used by emergency notification systems as support for adapting, communicating and sharing information among different sources and platforms.

Information included in SEMA4A is categorized into three main classes: (1) Accessibility; (2) Emergency; (3) Communication. The Accessibility class collects terms from two existing ontologies: the Web Authoring for Accessibility (WAfA), about the structural organization and navigation of web pages, and the AccessOnto ontology, related to accessibility requirements and in particular to guidelines defined by the Web Accessibility Initiative, Sun Micro Systems, IBM, Microsoft and Apple. SEMA4Âs second class, Emergency, together with the third one, Communication, include terms and relations about emergency and media technologies, extracted applying a semi-automatic technique that takes in input an existing taxonomy and the general purpose ontology WordNet (Miller, Beckwith, Fellbaum, Gross, & Miller, 1990).

In order to validate collected terms and relations, SEMA4A was evaluated both quantitatively and qualitatively (Malizia et al., 2010). The aim of the quantitative evaluation was to calculate two measures, such as coverage and accuracy, over a corpus of documents, to understand if the ontology was representative for selected domains. The qualitative evaluation was performed to value its usefulness, proposing a short questionnaire to two experts of accessibility and emergency management. Successively, results obtained from evaluators have been used to improve SEMA4A.

Another interesting characteristic of SEMA4A, that facilitates the interoperability with other platforms is the usage of OWL, a standard markup language for codifying collected knowledge through a formal semantics. Moreover, the consistency of its classes was verified with a reasoning tool called Pellet developed by Mindswap laboratory at Maryland University.

Finally, same authors have demonstrated the applicability of SEMA4A developing a prototype called CAP-ONES (Common Alerting Protocol-based Open Notification System) and presented in Malizia, Acuna, Onorati, Díaz Pérez, and Aedo (2009). The aim of CAP-ONES was to provide people with notifications about emergencies, personalizing them depending on users' abilities, characteristics of the situation and used technologies. For example, by performing a query over concepts and relations included in